

Biogeochemical Forensics of Fe-Based Microbial systems: Defining Mission Targets and Tactics for Life Detection on Mars

Director's Discretionary Fund (DDF) Project

This interdisciplinary project (see Cross Team Collaborations) is examining mineralogical and organic signatures of life in three different Fe redox-based microbial ecosystems on Earth in order to provide priority targets and guide analytical tactics for life detection in future missions to Mars. We are evaluating in detail the biogeochemistry of field sites that represent a range of scenarios in which Fe-based microbial ecosystems may produce identifiable biosignatures analogous to those to be sought on Mars: acidic Fe-rich sediments and concretions in Lake Tyrell, Victoria, Australia; partially-saturated, weathered Pliocene-age basalts in Box Canyon, Idaho; and neutral pH groundwater Fe springs in Alabama, Virginia, and Indiana. The fundamental goal is to understand how mineral phases formed in these environments may preserve (either directly as unique mineralogical alterations and/or fossils, or indirectly in the sequestering of organic compounds) indicators that life is or was present in a given habitat.

This project started in the fall of 2007, and to date we have conducted field trips to make in situ measurements and collect samples from Box Canyon (September 2007) and Lake Tyrell (August 2008). We have also extended (by way of pyrosequencing of Bacterial 16S rRNA genes) previous studies of neutral pH groundwater Fe seeps in Alabama and Virginia, and are making plans for a comprehensive field campaign at a groundwater Fe seep in Indiana in September 2008. The latter system is the focus of a current NASA Exobiology project ("Investigating Morphological and Isotopic Biosignatures of Terrestrial Iron Bacteria - A Potential Mars Analog") led by Juergen Schieber at Indiana University. Our most recent DDF-supported studies of materials from Box Canyon (see above) has confirmed previous findings that dissimilatory Fe(III)-reducing bacteria (both indigenous populations and other pure-culture strains) are capable of converting putative biogenic nanophase maghemite back to magnetite crystallites from which they were presumably derived. Detailed studies of the microbiological and mineralogical composition of materials from Lake Tyrell and the Indiana Fe seep will be conducted in the near future. These studies will include a combination of (1) targeted culture-based work as illustrated by the findings reported above for the Alabama groundwater Fe seep, Box Canyon and Lake Tyrell field sites; (2) organic biomarker analyses similar to those already underway (see above) with the Box Canyon (collaboration with Jennifer Eigenbrode from NASA Goddard and Marilyn Fogel of the Carnegie Institution of Washington) and Lake Tyrell (collaboration with UCB Ph.D. student Claudia Jones and Dr. Jochen Brooks of Australian National University) materials; and (3) pyrosequencing of large numbers (ca. 50,000 reads per sample) of Bacterial 16S rRNA genes (collaboration with Mitchell Sogin at Marine Biological Laboratory) using procedures that have recently (summer 2008) been applied to DNA extracts from nine previously-collected samples from Fe-based microbial ecosystems. An example of the data generated by pyrosequencing is given in Fig. 8 for a sample of surface sediment from Lake Tyrell. Other samples that were recently analyzed include: four samples from Box Canyon (two collected in 2005 and two collected in 2007); two samples from the Dragon Ridge groundwater Fe seep in Virginia (collected in 2006); one sample from the groundwater Fe seep in Alabama (collected in 2006); and one additional sample from Lake Tyrell (collected in 2007). Co-Is Roden and Emerson, together with postdoctoral researchers Marco Blothe

and Evgenya Shelobolina, are currently developing strategies for data reduction and presentation of the pyrosequencing results.